Stream Discharges for Water Supplies

Introduction

Four cities in Missouri that rely on stream flow for their water supply are Joplin, Perryville, Poplar Bluff and Trenton. Joplin depends on Shoal Creek, Perryville uses Saline Creek, Poplar Bluff uses Black River, and Trenton uses Thompson River. Stream flow must be adequate to meet withdrawal by the city. Flow must provide enough for downstream flow to meet in-stream-flow requirements. Monthly low flow-duration analysis was made to determine the probability of stream flow depletion.

Stream Flow Analysis:

Many communities in Missouri utilize creeks and rivers to meet their municipal needs. Some streams do not have enough flow to meet immediate needs and off channel storage is required. Other streams, primarily in the Ozark Region where springs provide sufficient flow, have continuous discharges to meet consumptive use requirements.

Basic data for making stream flow frequency analysis was obtained from USGS published water supply papers. Mean daily discharges were used to analyze stream flow volumes and frequencies. Gages having long term records were used to evaluate extended periods of drought. Gage data is published as mean daily discharge, in cubic feet per second. Analysis was made on a monthly basis. A comparison of a shorter drought of seven days is also presented.

To meet in-stream flow requirements, the 7-day duration, 10-year frequency mean discharge was determined. Only when flows exceeded the in-stream flow requirements were withdrawals allowed for domestic uses.

All frequency analysis was made using the “Log-Pearson Type III Probability Method”. This procedure is described on the Water Resource Council Bulletin 17B.

To establish base flow in the streams, USGS computer program “HYSEP” was used. The program separates the base flow hydrograph from the total discharge hydrograph.

The monthly frequency analysis was also compared to historical stream flows of the 1950’s drought of record. This identified the months of critical stream flow that could be expected to occur during an extreme drought.

All analysis results are presented in a series of charts displayed for each month of the year.

Glossary

Definition of terms

cfs – Discharge in cubic feet per second.
MG -- million gallon
MGD – million gallon per day
GPM – gallon per minute
USGS – United States Geological Survey
Acre feet – Volume of water covering one acre, one foot deep.
USGS Bulletin 17B - The USGS Guideline for Determining Flood Flow Frequency. It describes the data and procedures for computing flood flow frequency curves where systematic stream gauging records are of sufficient length to warrant statistical analysis.

Log-Pearson Type III Probability Method. The annual values are fit to a Log-Pearson Type III probability distribution. If minimum values are used, the result is non-exceedence probabilities. If the maximum values are used the result is exceedence probabilities.

The observations are fit to the Log-Pearson Type III distribution using the following equation:

$\log Q = X+KS$

where Q is the expected discharge, X is the mean logarithm of the observed values, S is the standard deviation of logarithms of the observed values and K is a factor that is a function of the skew coefficient of the observed values and the selected non-exceedence probability.

7 day Q10 – The mean 7-day duration, 10-year frequency low flow is the minimum flow needed for in-stream flow requirements.

HYSEP - A USGS computer program that separates the base flow hydrograph from the total hydrograph.

Runoff in Watershed (inches) – The volume of runoff from the entire drainage area of the Basin, in inches.

WHPA Report – Report on problems of the Ozark aquifer and associated problems with supply and demand. Titled “Source of Supply Investigation for Southwestern Missouri.” Prepared by Wittman and associates.

JOPLIN, MISSOURI
Water Supply Study
Shoal Creek

Introduction:

This analysis was made to assess the availability of Joplin's water supply. Joplin obtains their water supplies from a combination of Shoal Creek and wells. Shoal Creek being the major contributor. There are 8 to 14 million gallon per day pumped from Shoal Creek, which is fed by numerous springs throughout its drainage area. Wells contribute 1.2 to 1.9 million gallons per day. The first part of this report discusses availability of stream flow and withdrawals from Shoal Creek. The second part of the report addresses contributions by wells. The "WHPA" report assesses the problems associated with excessive use of ground water in the region.

Discussion:

Shoal Creek:

Shoal Creek Stream gage above Joplin is located 1400 feet downstream of state Highway 86. The drainage area above the stream gage is 427 square miles. The water supply is provided by "Missouri-American Water Company". The pump intake is located ¾ mile downstream of highway I-44, about 4.5 miles downstream of the gage (NE ¼, sec 28, T27N, R33W). Stream flow data was obtained from USGS water supply papers, daily values. Mean daily discharges were used to analyze stream flow volumes and frequencies. Continuous records have been kept from 1941 through 2002. Neosho also uses water from Shoal Creek. Their intake is about 25 miles upstream of the stream gage above Joplin. Neosho takes an average of 1.6 MGD from Shoal Creek.

Joplin has no facility for storing raw water off channel.

Annual precipitation amounts for most of Missouri have been increasing. This is shown in the state water plan. The study was recently made for the state by Steve Hue (Former state climatologist at University of Missouri) to update Climate data. Annual rainfall has increased several inches in the last 30 years. **Figure 40.1** illustrates the annual precipitation and trend for Joplin. This station shows the trend in annual precipitation increasing from 35 inches to 50 inches, an increase of 42% for the years 1950 through 2000.

Figures 40.2.a and 40.2.b show the effect of increased annual rainfall on runoff. The trend indicates an increase in total annual runoff from 12.5 inches to 19 inches or approximately 52% from 1950 to year 2000. These two figures are displayed in terms of watershed inches and also cubic feet per second.

The drought of record was in the 1950's. Non-excedence probabilities for the 1%, 2% and 4% chance flows in **figure 40.7** are compared to actual stream flow records in **figures 40.3.a through 40.3.d** for the drought of record (1953 through 1956). All flows exceeded 7-day Q-10 flow for these years except August 1954, when mean flow fell to 37 cfs or 57.2 million gallons per day.

Figure 40.3.a compares 1953 mean monthly flow to monthly probability shown in figure 7.
Figure 40.3.b compares 1954 mean monthly flow to monthly probability shown in figure 7.
Figure 40.3.c compares 1955 mean monthly flow to monthly probability shown in figure 7.
Figure 40.3.d compares 1956 mean monthly flow to monthly probability shown in figure 7.

Base flow separation was made using the USGS computer program, HYSEP. HYSEP separates the base flow hydrograph from the total hydrograph. This analysis was made to estimate sustained flow, in order to establish availability of continuous stream flow. **Figure 40.4.a** is the base flow index and is the ratio of base flow to total stream flow. This chart shows the yearly fluctuation in base flow indexes and indicates the trend. The trend has increased from 26% of total runoff in 1955 to 38% in 2000. About 50 percent increase. **Figure 40.4.b** displays volume of base flow in terms of watershed inches of runoff. **Figure 40.4.c** shows the base flow in terms of mean cfs. The trend shows the mean base flow to be about 450 cfs or 696 million gallons per day for year 2000.

To determine the rate of flow needed to meet in-stream flow requirements, the 7-day Q-10 low flow was determined using the period of record, 1950 through 2000. **Figure 40.5** shows the results of the frequency analysis to be 43 cfs. For purposes of pumping from the creek, discharge needed to exceed 43 cfs.

Mean seven-day annual low flows for 1942 through 2000 were calculated and are shown in **figure 40.6.** The lowest 7-day discharge occurred September 1954 with a mean value of 16 cfs.

Monthly non-excedence probabilities (low flows) for 1% chance of occurrence (1 time in 100 years), 2% chance (1 time in 50 years) and 4% chance (1 time in 25 years) were established from stream flow data for the years 1951 through 2000. **Figure 40.7** displays these results. The mean monthly flows for the 1% chance of occurrence are equal to, or slightly below the 7-day 10-year frequency low flow (43 cfs or 66.5 million gallons per day) for 7 months. The months are January, through March, August and October through December. The remaining months exceed 7-day Q-10 flows. The 2% and 4% flows exceed the 7-day Q-10 for all months. For this report, all statistical determinations were made using the Log Pearson type 3 method as described in Water Resource Council bulletin 17B.

Figure 40.8.a shows low flow not expected to be less than, or non-excedence probability for the 1% chance of low flow compared to the flow needed to meet demand. This indicates that eight months out of the year stream flow is adequate for pumping and allowing the 7-day 10-year frequency discharge to pass down stream. **Figure 40.8.b** is the two percent chance of occurrence and indicates only 2 months, November and December, are close to the minimum but probably would allow pumping. **Figure 40.8.c** shows that the 4% chance of occurring is able to provide enough flow so that there is only a very small deficit in November. **Figures 40.8.d and 40.8.e** display the deficits in bar charts, one showing the deficit in acre-feet and the other in terms of cfs.

The following shows the average daily and yearly water withdrawal from Shoal Creek, at Joplin, for the period 1995 through 2002. Usage has been fairly constant. Daily data for this time period was submitted by the "Missouri-American Water Company" and can be observed in file "Shoal Creek pumpage.xls".

Year	Daily Withdrawal	Yearly Withdrawal
1995	0.467 MGD	3,453.290 million gallon
1996	10.916 MGD	3,995.330 million gallon
1997	10.650 MGD	3,878.840 million gallon
1998	12.068 MGD	4,406.896 million gallon
1999	11.207 MGD	4,090.036 million gallon
2000	10.990 MGD	4,024.792 million gallon
2001	10.608 MGD	3,876.281 million gallon
2002	10.825 MGD	3,957.166 million gallon

Figure 40.9 shows the trend in annual water withdrawal for Joplin, from Shoal Creek, is slowly increasing from 10.6 million gallon per day in 1995 to 11.2 million gallon in 2002. A 5.5 percent increase. This figure also shows the volume of water that is used from wells to be about 1 MGD to supplement Shoal Creek withdrawal.

Neosho also obtains their water supply from Shoal Creek. Their intake point is about 25 miles upstream of Joplin. Their remaining needs, not met by Shoal Creek, are obtained from wells. Following are the average daily and yearly water withdrawal, from Shoal Creek, for Neosho for the period 1997 through 2001. Monthly data for this time period was obtained from the "Missouri Major Water Users Unit" of Missouri Department of Natural Resources. Because Neosho is located upstream of the Joplin stream gage, this withdrawal is accounted for in the analysis of stream flow data.

Neosho water use from Shoal Creek.

Year	Daily Withdrawal	Yearly Withdrawal
1997	1.220 MGD	445.335 million gallon

1998	1.233 MGD	499.965 million gallon
1999	1.617 MGD	590.220 million gallon
2000	1.916 MGD	699.344 million gallon
2001	1.943 MGD	709.376 million gallon

Additional comparisons for the 1950's drought were made at the Joplin intake point using the mean 7-day low flow for examination of a shorter duration. These comparisons are shown in **figures 40.10.a, 40.10.b, 40.10.c and 40.10.d**. These figures indicate short-term (7-day duration) mean low flows during the drought of record, by months, for years 1953, 1954, 1955 and 1956. For 1953, September and October, flows nearly equaled 43 cfs (7-day Q-10 flow). In 1954, the driest year on record, June through September mean flows were below 43 cfs. In 1955 and 1956 all mean flows were at or above 43 cfs except for October 1956 when mean flow was 39 cfs.

JOPLIN, MISSOURI
Water Supply Study

Wells

Deep wells in this region are in the Ozark aquifer. Because of the increasing demand in the area, it is becoming harder for this aquifer to meet the needs. A ground water study has been made for the region by "WHPA". Titled "Community Data Report, Source of Supply Investigation for Southwestern Missouri". It is available on the Internet at www.wittmanhydro.com.

This report describes wells in the region and associated problems.
Following is information on wells and withdrawal rates that are reported for each city. These are:

Carl Junction, Mo. has 7 wells with 6 currently in use and plan to drill 2 more.
In 2000 they pumped 201.5 million gallon, an increase of 37% since 1987.

Carterville, Mo. has one well and yielded 74 million-gallon in 2001, an increase of 16% since 1994.

Carthage, Mo. has 17 wells of which 16 are currently being used. In year 2000, there were 1,126 million gallons were pumped, an increase of 39% since 1987.

Duenweg, Mo. has 2 wells in use pumping 41 million gallons per year. The demand has increased 18% since 1987.

Jasper rural water district number one has one well and pumped 60 million-gallon per year in 2001. Two additional wells are planned.

Neosho, Mo. has 5 wells that pump 429 million gallons per year in year 2000, an increase of 28% since 1997, when they began pumping from wells.

Oronogo, Mo. has two wells that pump a combined amount or 45 million-gallon, an increase of 81% from 1990 to 2000.

Pittsburg Ks. has 4 wells and pump about 1,000 million gallons annually with very little change in demand.

Webb City Mo. has 13 wells with only 7 in use. They are pumping 400 million gallons per year.

Not found in the summary report is the Joplin well usage.
Joplin has 6 wells to supplement their water supply from Shoal Creek. The combined annual pumping rates for 1996 through 2002 are listed below. Monthly values are available and may be observed in file "well_pumpage.xls".

JOPLIN, MISSOURI, Water Supply
Drought Study

Year	Yearly Withdrawal
1996	143.366 million gallons
1997	176.914 million gallons
1998	140.504 million gallons
1999	201.697 million gallons
2000	342.766 million gallons
2001	244.248 million gallons
2002	431.388 million gallons

Conclusion:

Because of the many springs in the drainage area of Shoal Creek, the mean monthly minimum flows were never depleted. The minimum low flow for the period of record was 16 cfs in August and September of 1954. This low flow stayed below 20 cfs for 14 days in succession. For the period 1979 through 2000, the minimum mean daily low flow was 30 cfs in 1981 and was below 55 cfs for 2 days. These two times are the only times flow was below the 7-day Q-10 low flow for the period of record.

Joplin's water demand has increased during the period 1995 through 2002 at a rate of 0.20 MGD or 1.9% per year.

The 7-day 10-year frequency discharge of 43 cfs exceeded the 1% chance or 1 year in 100 years, low flows for seven months, mean monthly Shoal Creek discharges were between 2 and 5 cfs less. These months are January, February, March, August, October, November and December. For the 2% chance or 1 year in 50 years, all monthly mean flows exceeded the 7-day Q-10 flows.

During the 1950's there were no months that flow in Shoal Creek would not allow pumping for at least some of the month. However there would be shorter periods of time flows would be too low for pumping. This is indicated by the 7-day low mean discharge values for 1953, 1954, 1955 and 1956. Each year had mean 7-day duration flows below pumping range.

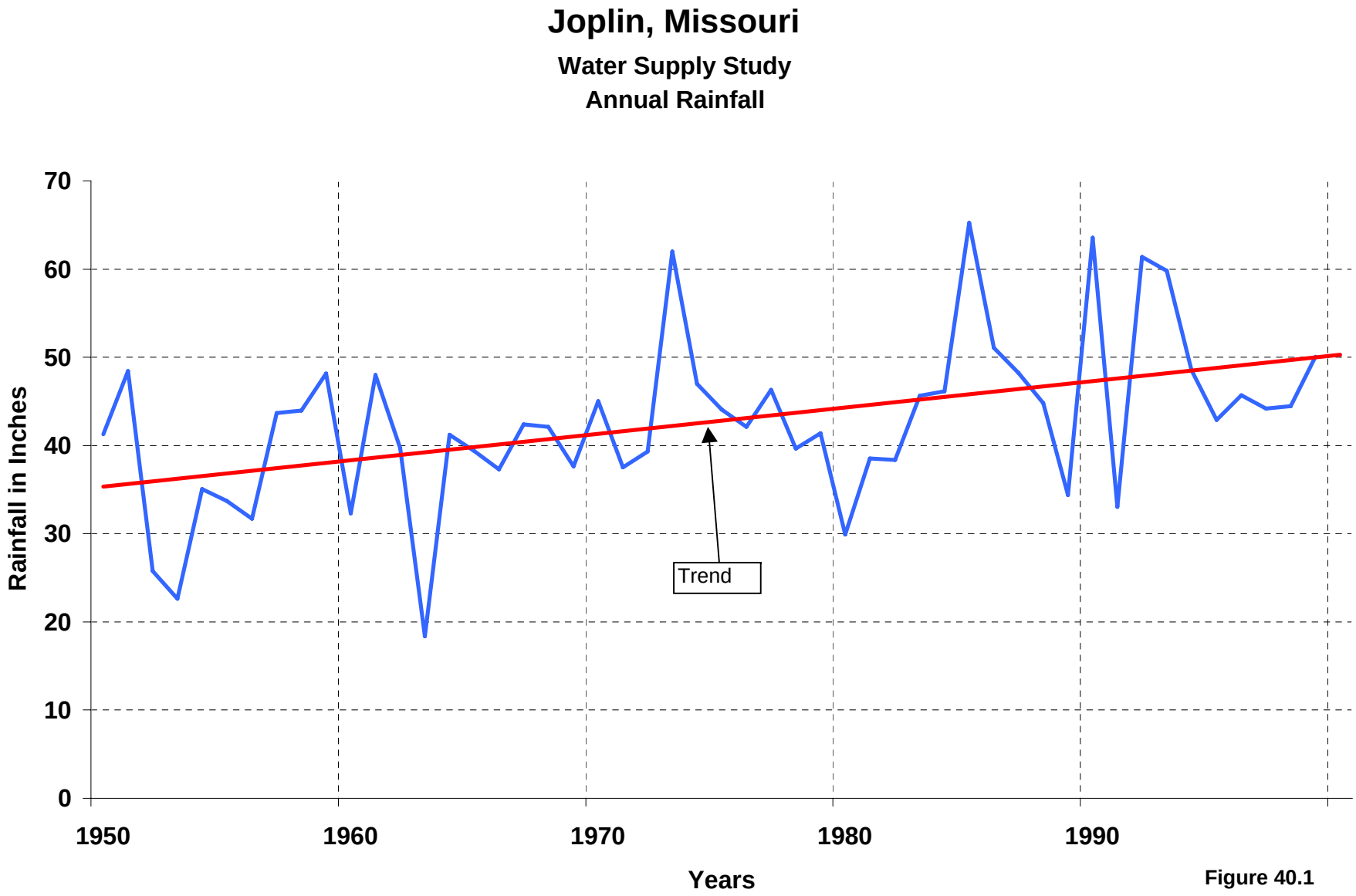

Joplin, Missouri
Water Supply Study
Annual Rainfall
Rainfall in Inches
70
60
50
40
30
20
10
0
1950
1960
1970
1980
1990
Years
Trend

Figure 40.1

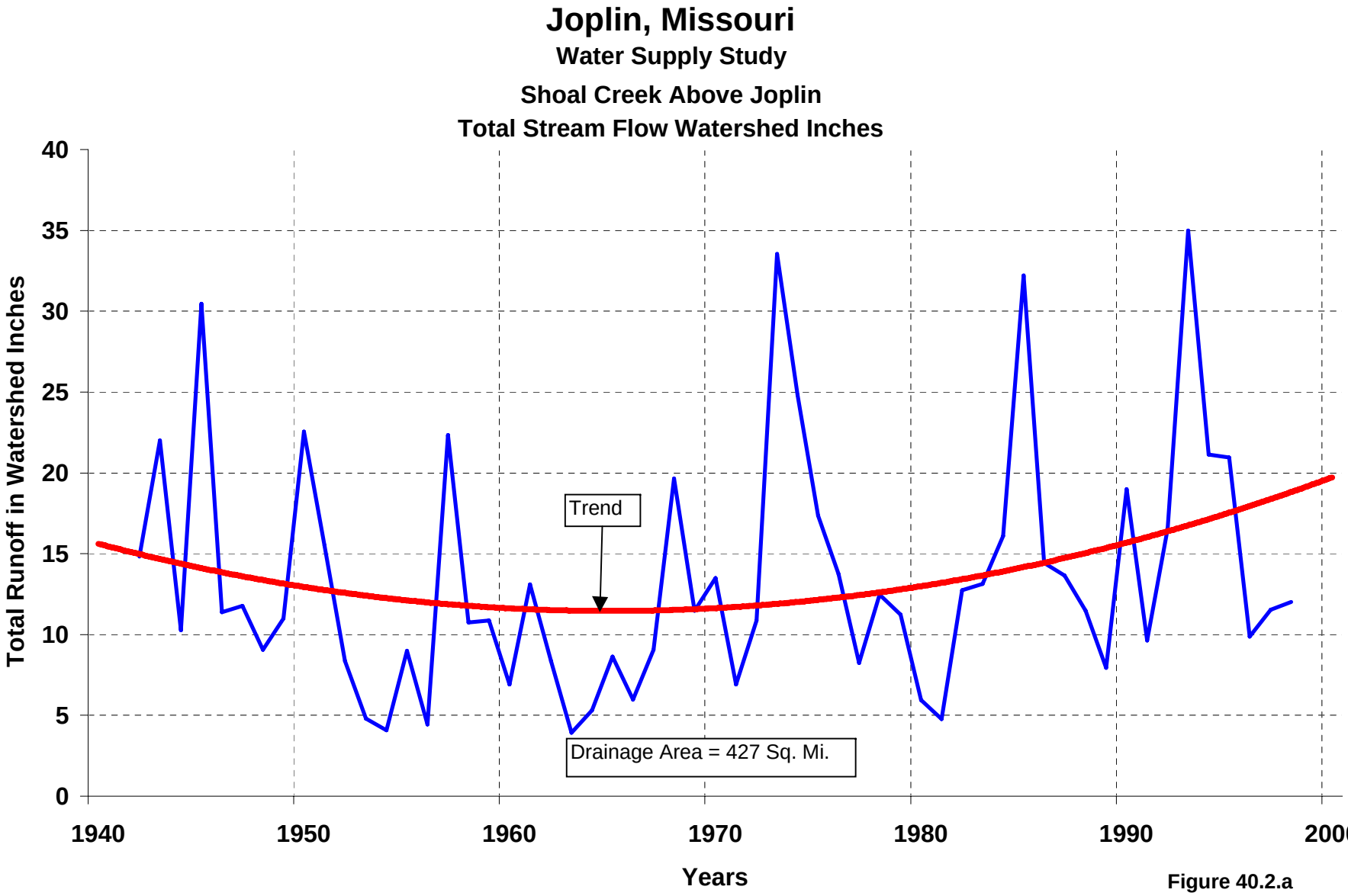

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Total Stream Flow Watershed Inches
Total Runoff in Watershed Inches
40
35
30
25
20
15
10
5
0
1940
1950
1960
1970
1980
1990
2000
Years
Trend
Drainage Area = 427 Sq. Mi.

Figure 40.2.a

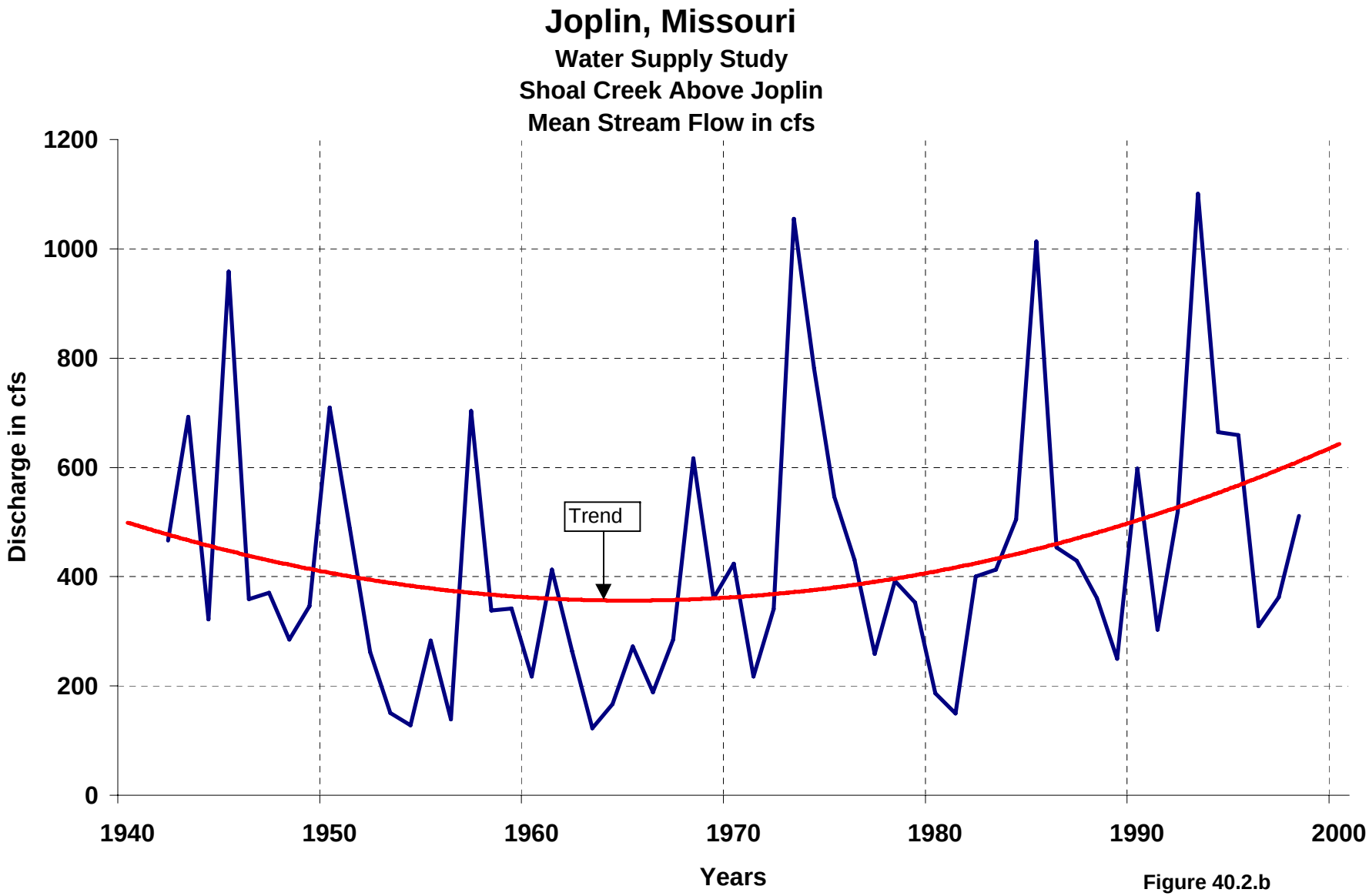

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Mean Stream Flow in cfs
Discharge in cfs
1200
1000
800
600
400
200
0
Trend
1940
1950
1960
1970
1980
1990
2000
Years

Figure 40.2.b

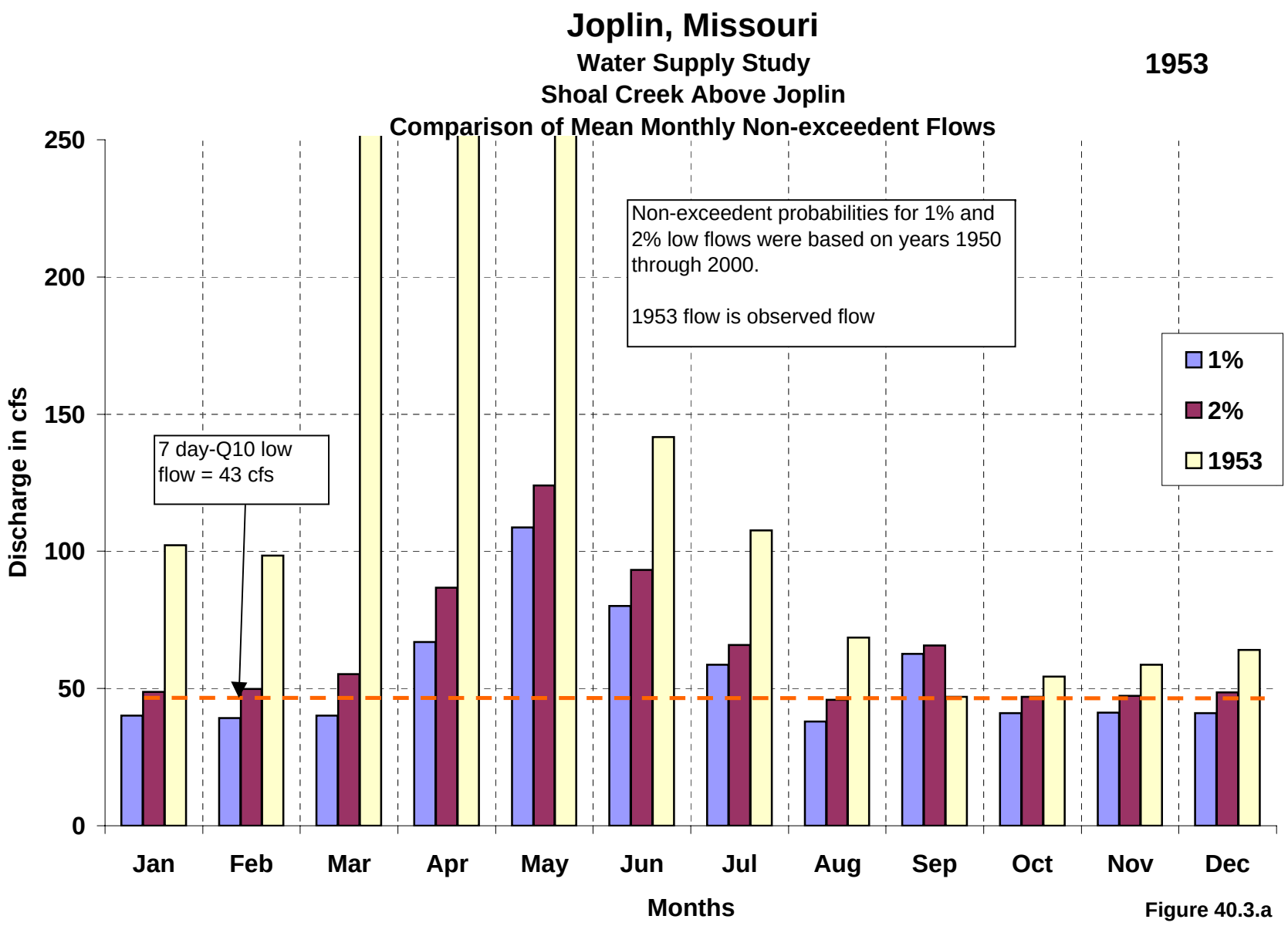

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Comparison of Mean Monthly Non-exceedent Flows
1953
Non-exceedent probabilities for 1% and 2% low flows were based on years 1950 through 2000.
1953 flow is observed flow
7 day-Q10 low flow = 43 cfs
1%
2%
1953
Discharge in cfs
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 40.3.a

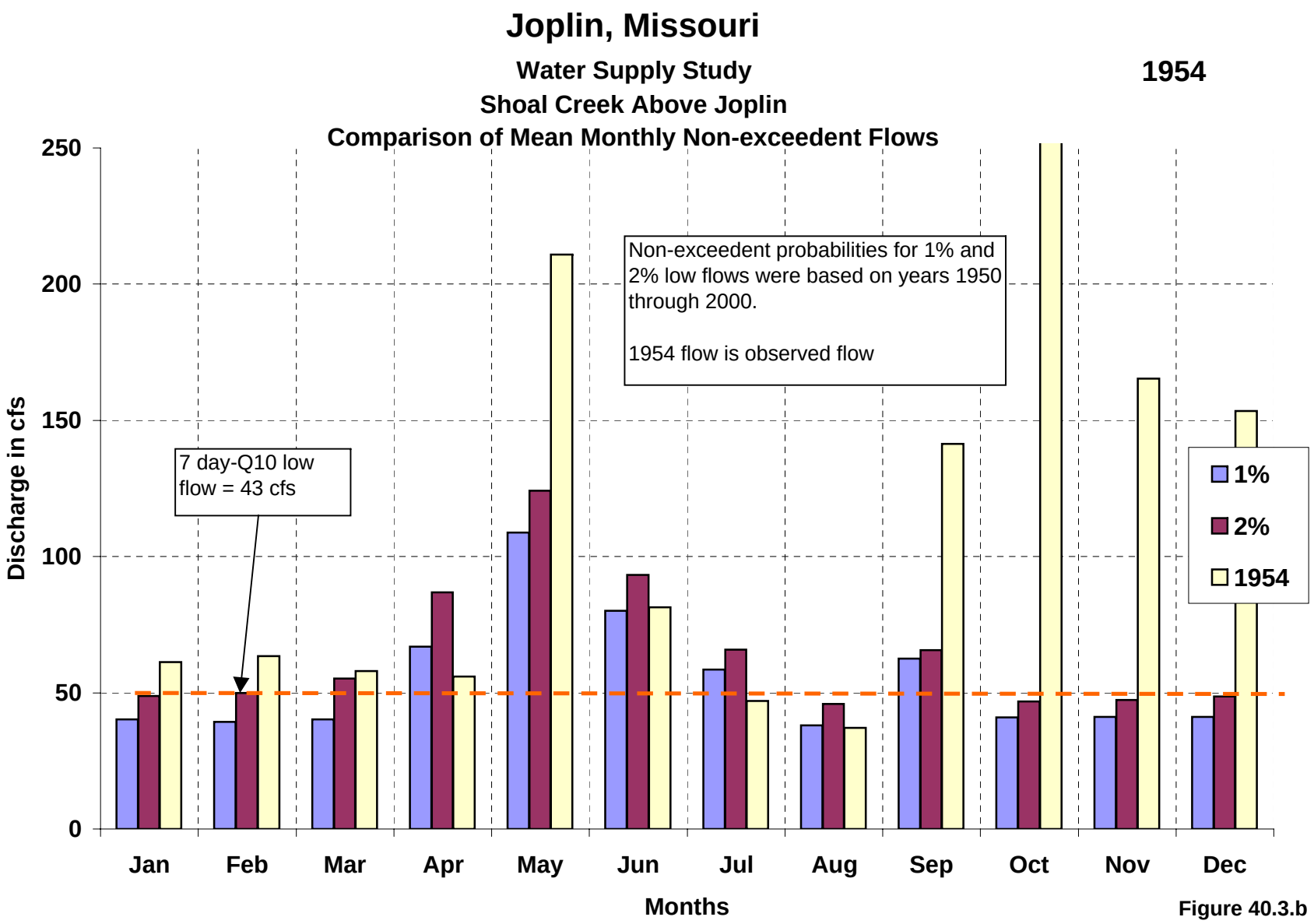

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Comparison of Mean Monthly Non-exceedent Flows
1954
Non-exceedent probabilities for 1% and 2% low flows were based on years 1950 through 2000.
1954 flow is observed flow
7 day-Q10 low flow = 43 cfs
1%
2%
1954
Discharge in cfs
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 40.3.b

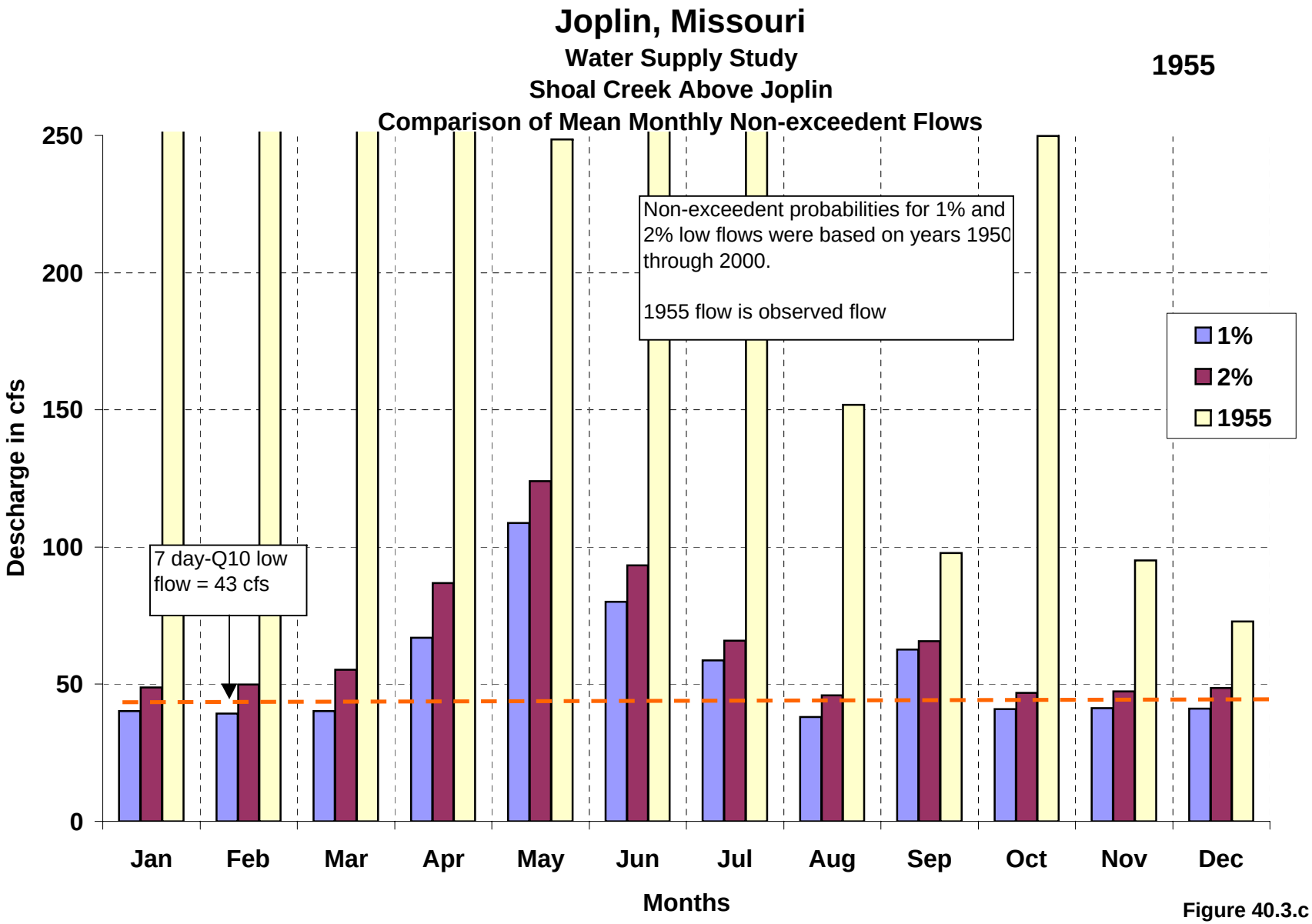

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Comparison of Mean Monthly Non-exceedent Flows
1955
Non-exceedent probabilities for 1% and 2% low flows were based on years 1950 through 2000.
1955 flow is observed flow
7 day-Q10 low flow = 43 cfs
1%
2%
1955
Descharge in cfs
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 40.3.c

Joplin, Missouri

Water Supply Study

Shoal Creek Above Joplin

Comparison of Mean Monthly Non-exceedent Flows

1956

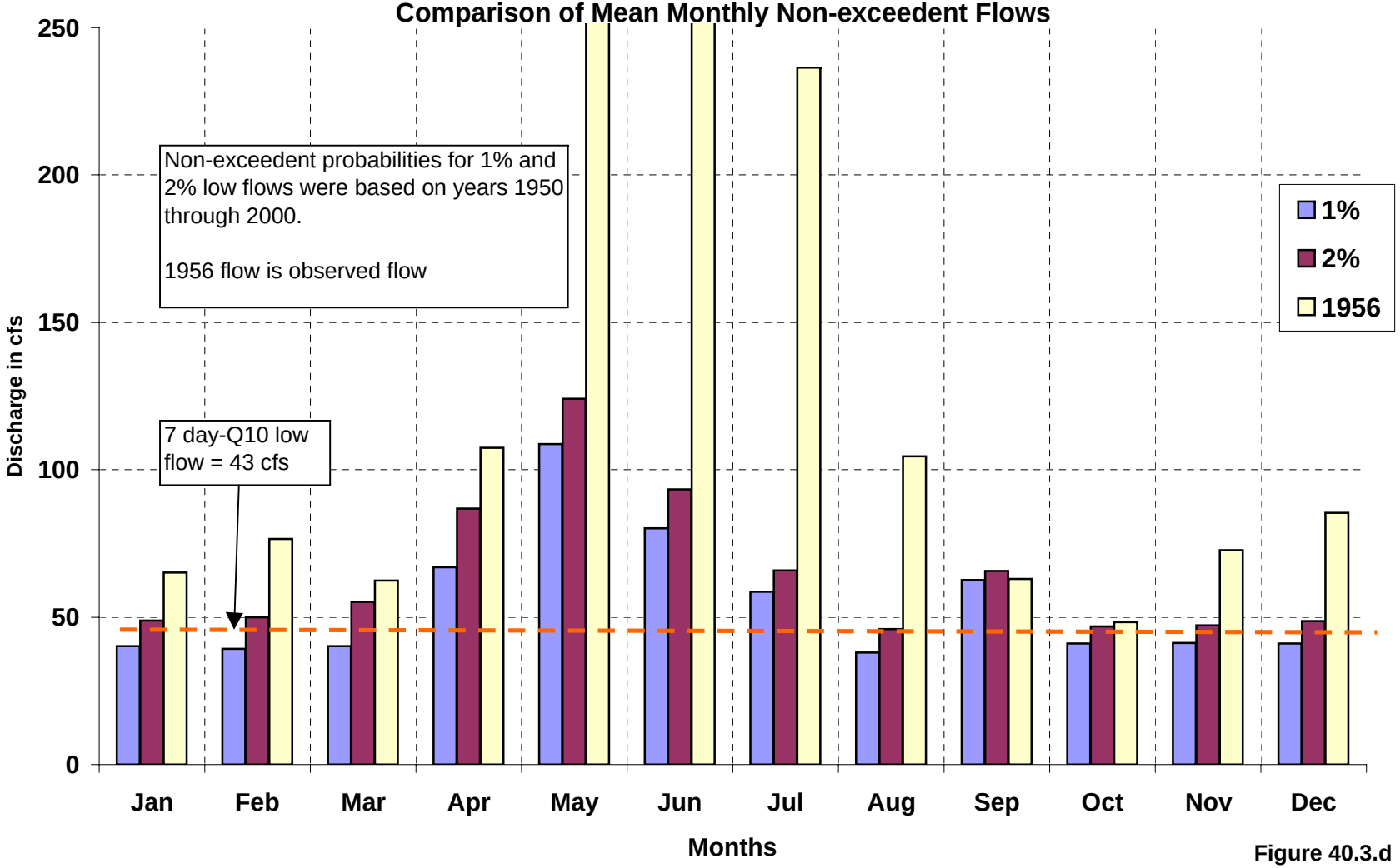


Figure 40.3.d

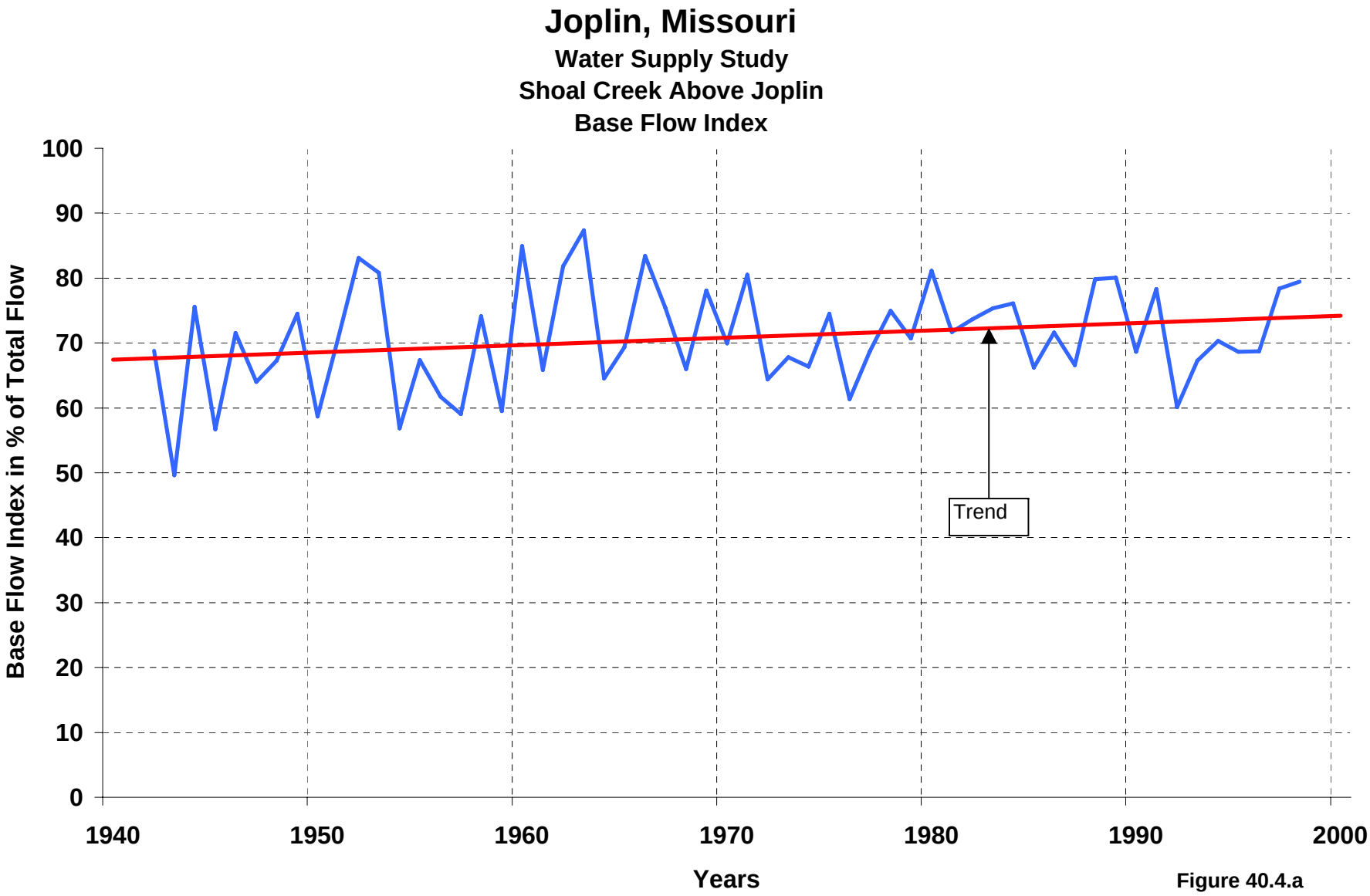

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Base Flow Index
Base Flow Index in % of Total Flow
100
90
80
70
60
50
40
30
20
10
0
1940
1950
1960
1970
1980
1990
2000
Years
Trend

Figure 40.4.a

Joplin, Missouri

Water Supply Study

Shoal Creek Above Joplin

Total Base Flow In Inches

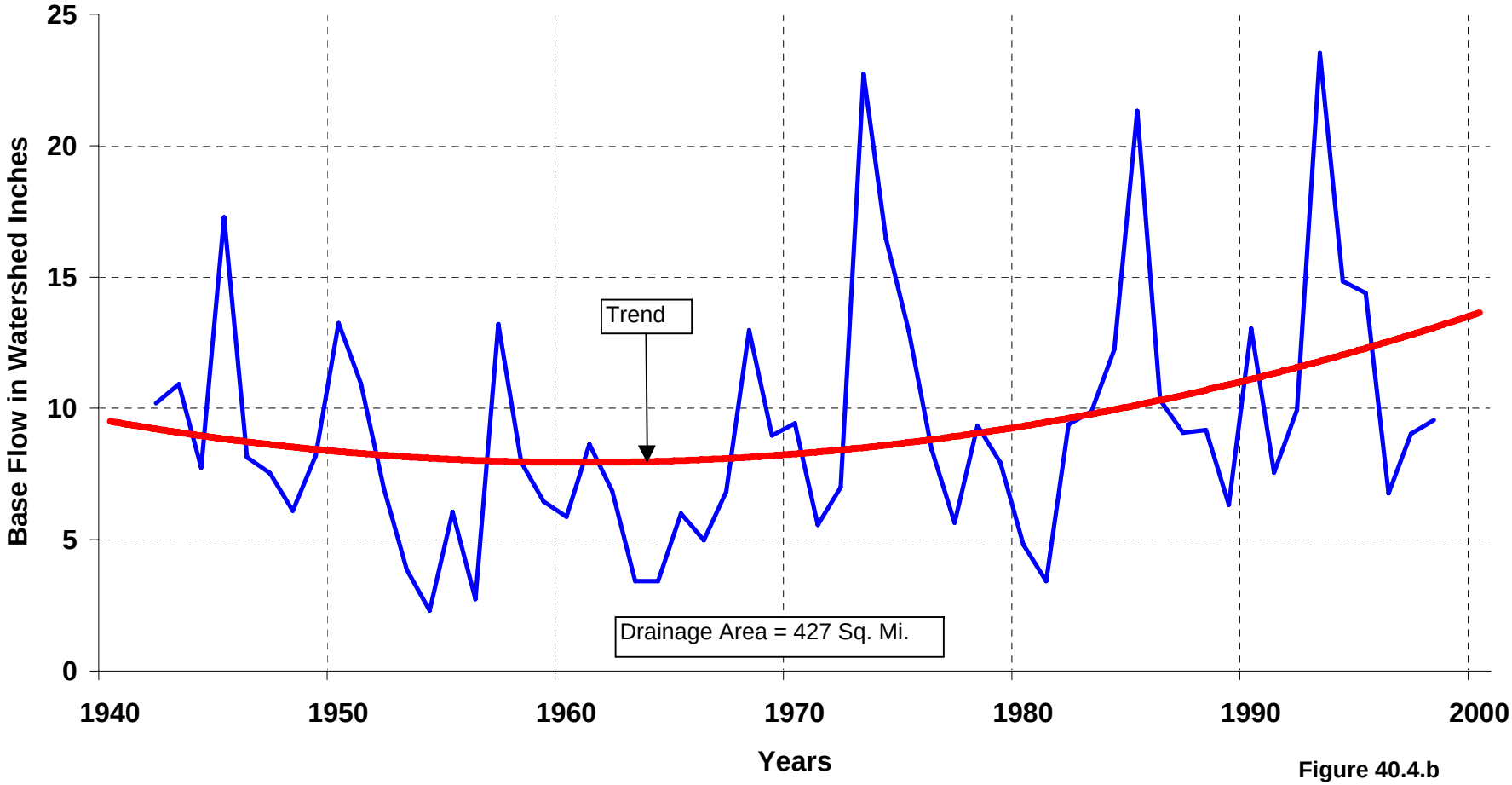


Figure 40.4.b

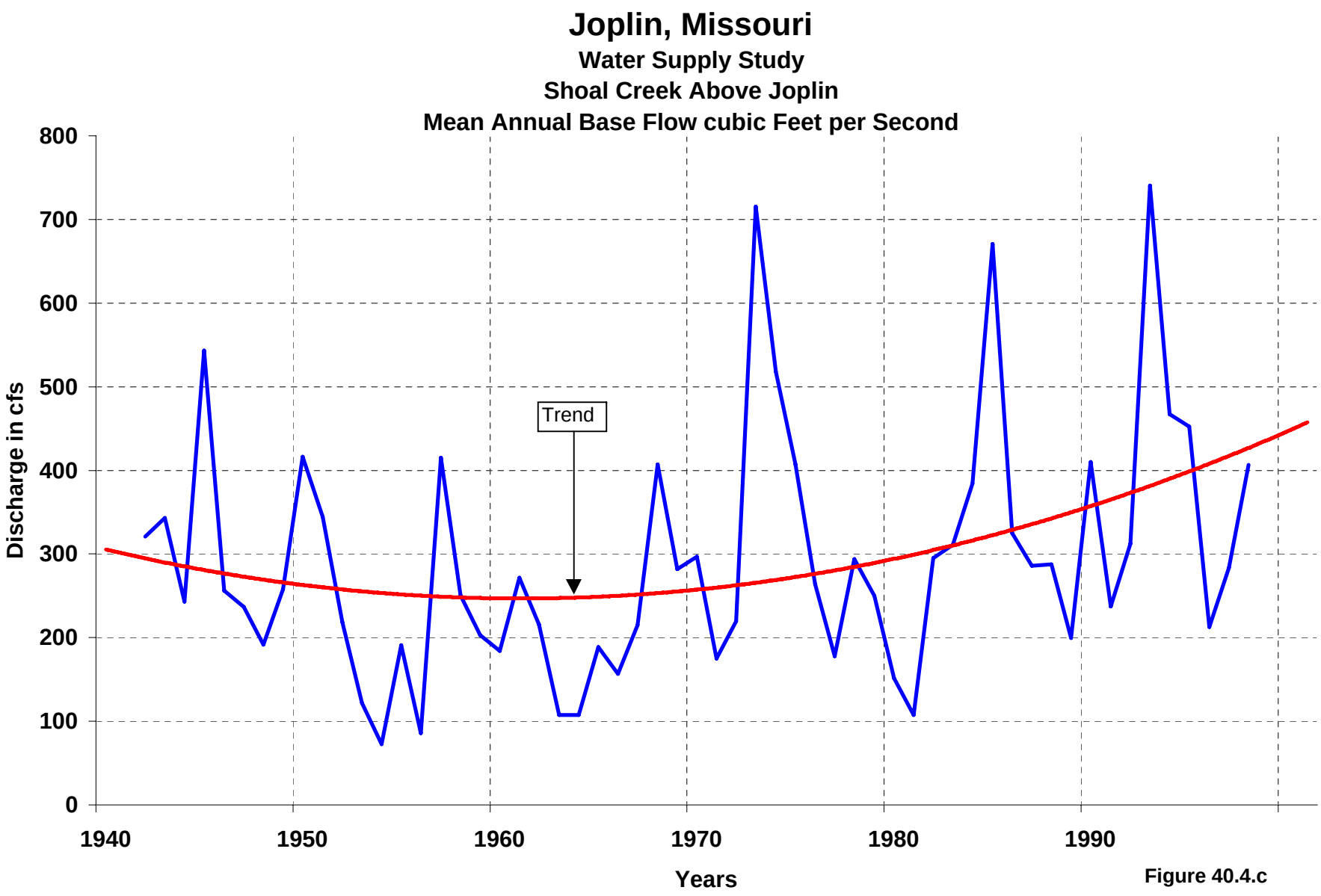

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Mean Annual Base Flow cubic Feet per Second
Discharge in cfs
800
700
600
500
400
300
200
100
0
Trend
1940
1950
1960
1970
1980
1990
Years

Figure 40.4.c

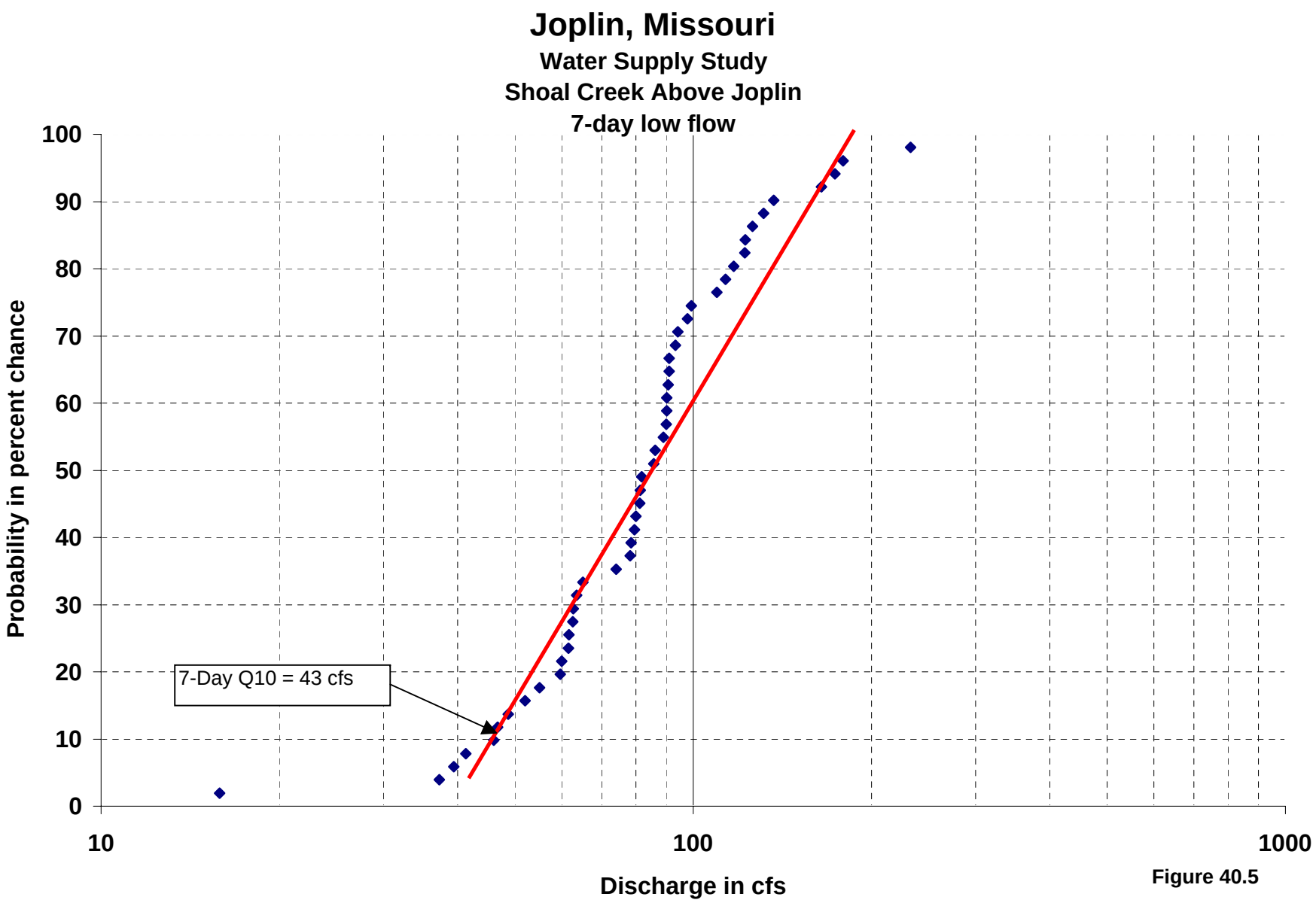

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
7-day low flow
Probability in percent chance
100
90
80
70
60
50
40
30
20
10
0
7-Day Q10 = 43 cfs
10
100
1000
Discharge in cfs

Figure 40.5

SHOAL CREEK

Water Supply Study
Shoal Creek Above Joplin
Annual Mean 7-Day Low Flow

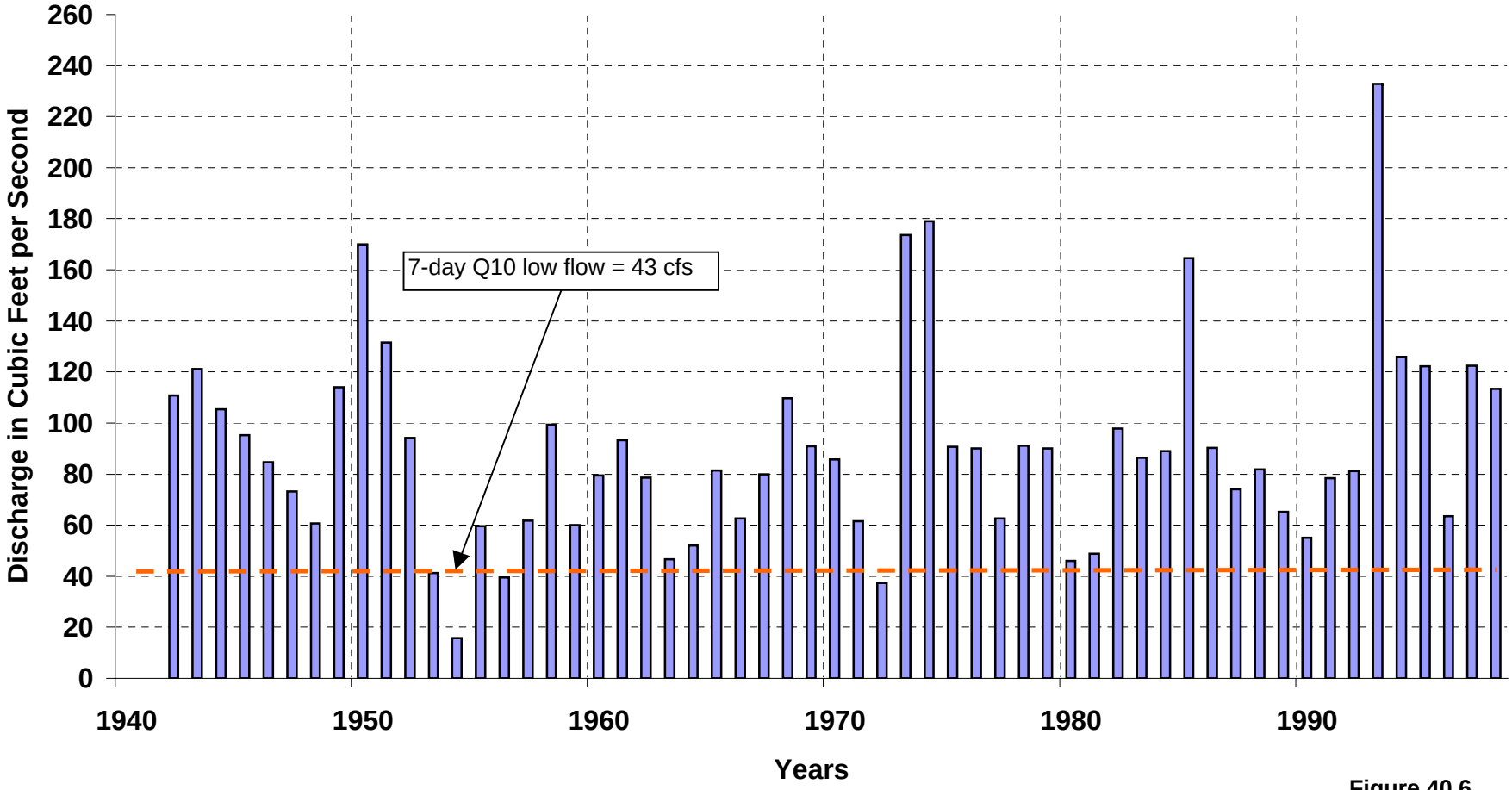


Figure 40.6

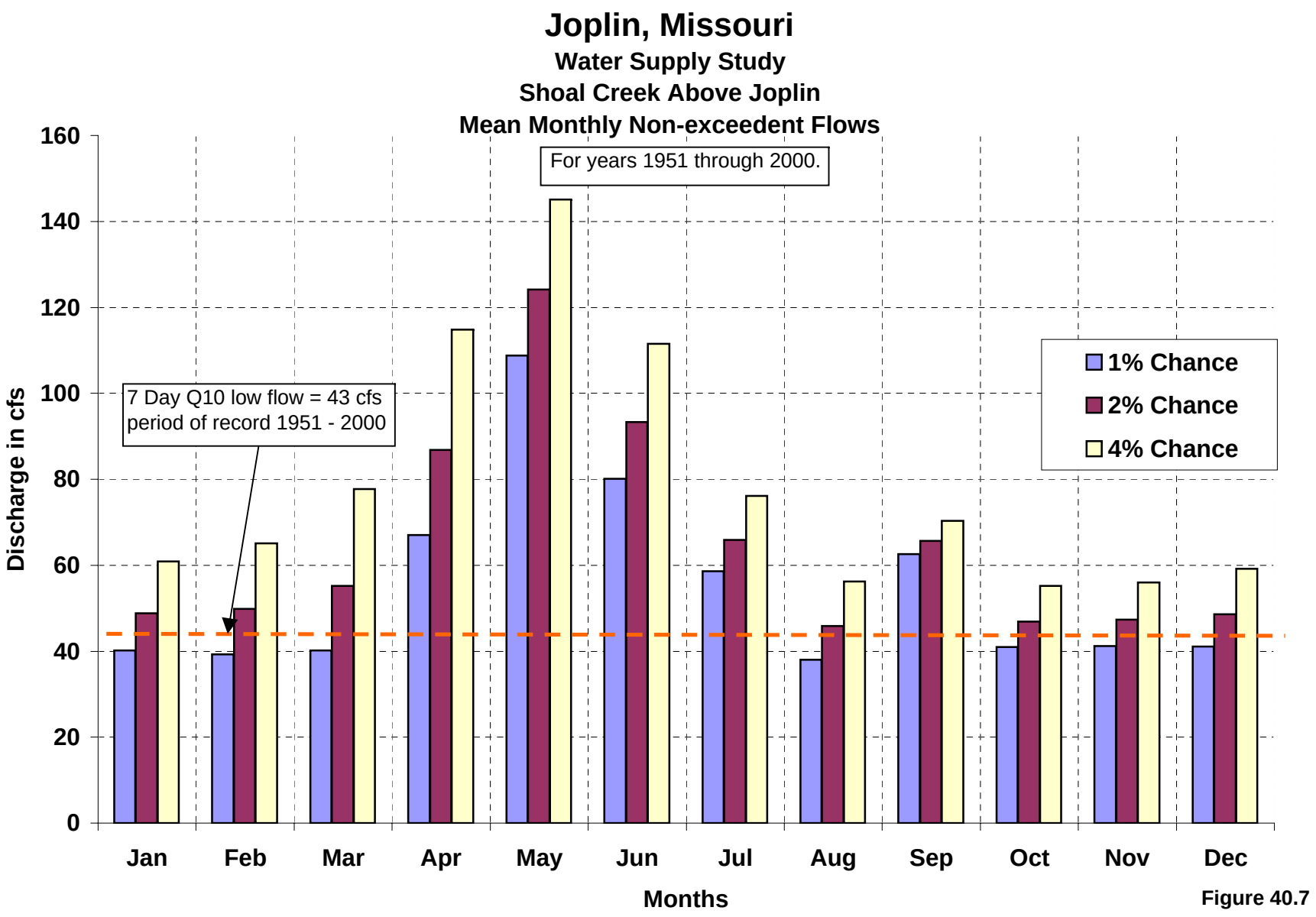

Joplin, Missouri
Water Supply Study
Shoal Creek Above Joplin
Mean Monthly Non-exceedent Flows
For years 1951 through 2000.
7 Day Q10 low flow = 43 cfs
period of record 1951 - 2000
1% Chance
2% Chance
4% Chance
Discharge in cfs
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

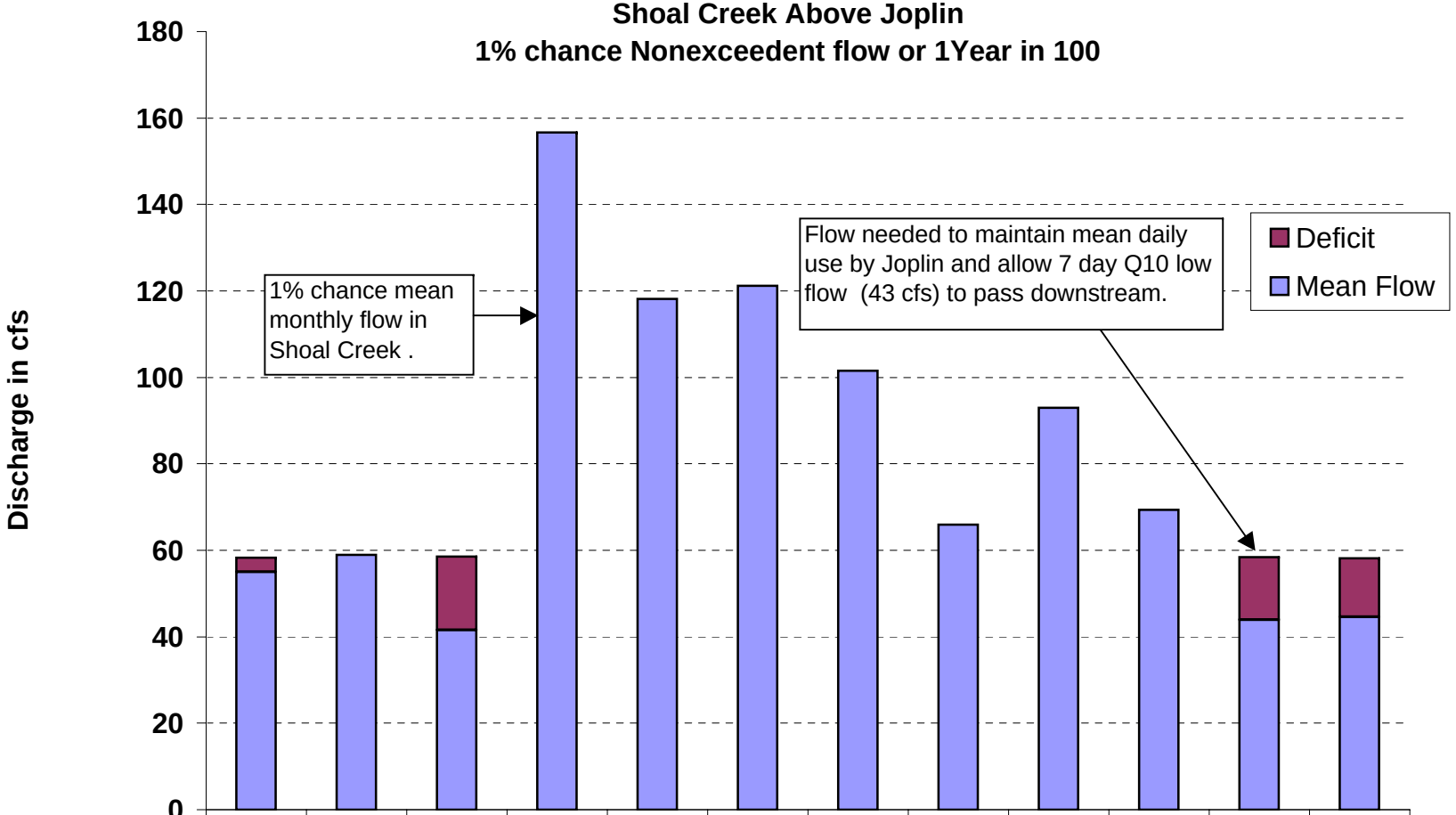
Figure 40.7

Joplin, Missouri

Water Supply Study

Shoal Creek Above Joplin

1% chance Nonexceedent flow or 1Year in 100



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit	3.27	0.00	17.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.49	13.61
Mean Flow	55	58.9	41.5	156.6	118.1	121.2	101.5	66	93	69.3	43.9	44.6

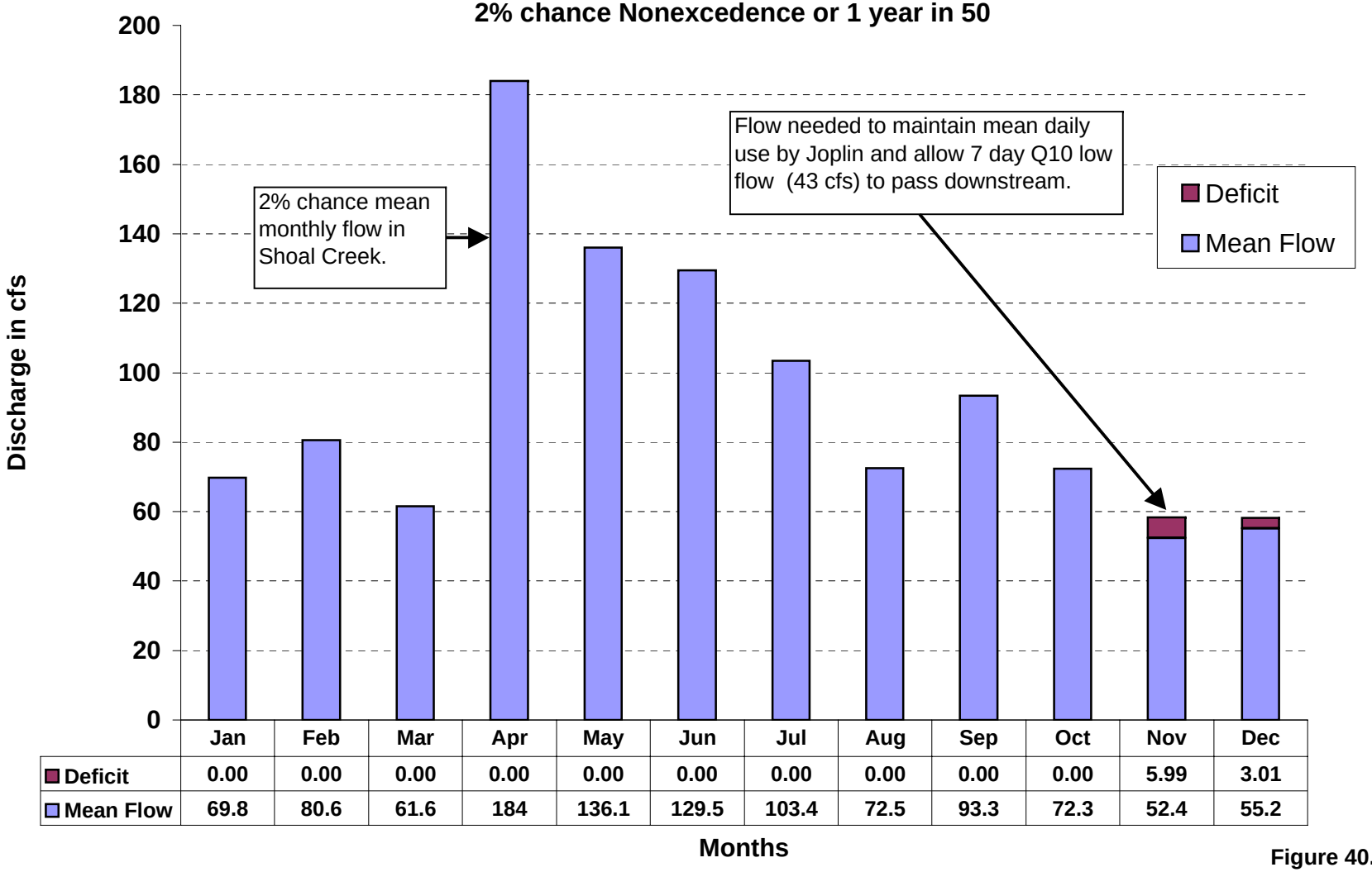
Figure 40.8.a

Joplin, Missouri

Water Supply Study

Shoal CreekAbove Joplin

2% chance Nonexcedence or 1 year in 50



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.99	3.01
Mean Flow	69.8	80.6	61.6	184	136.1	129.5	103.4	72.5	93.3	72.3	52.4	55.2

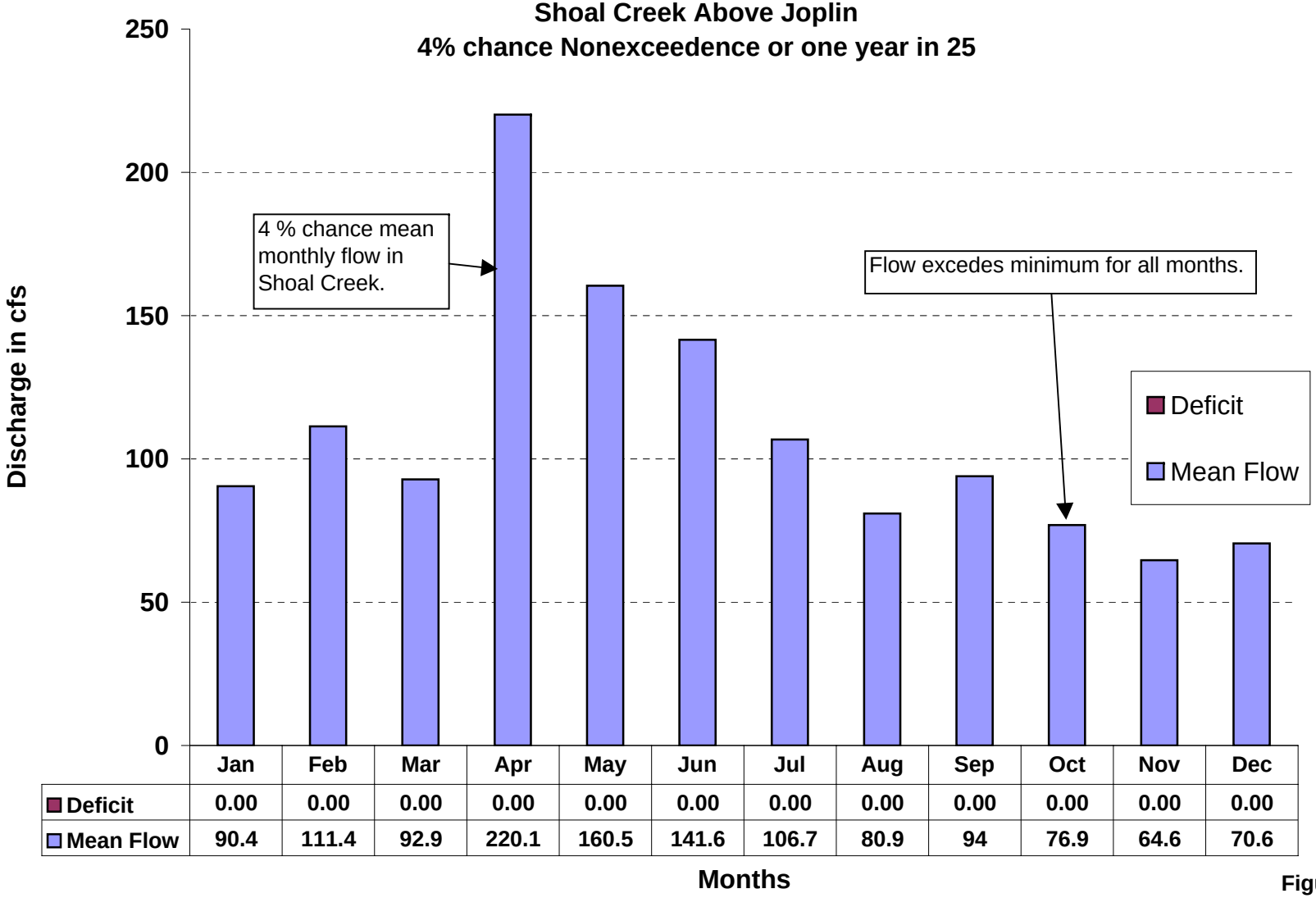
Figure 40.8.b

Joplin, Missouri

Water Supply Study

Shoal Creek Above Joplin

4% chance Nonexceedence or one year in 25



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean Flow	90.4	111.4	92.9	220.1	160.5	141.6	106.7	80.9	94	76.9	64.6	70.6

Figure 40.8.c

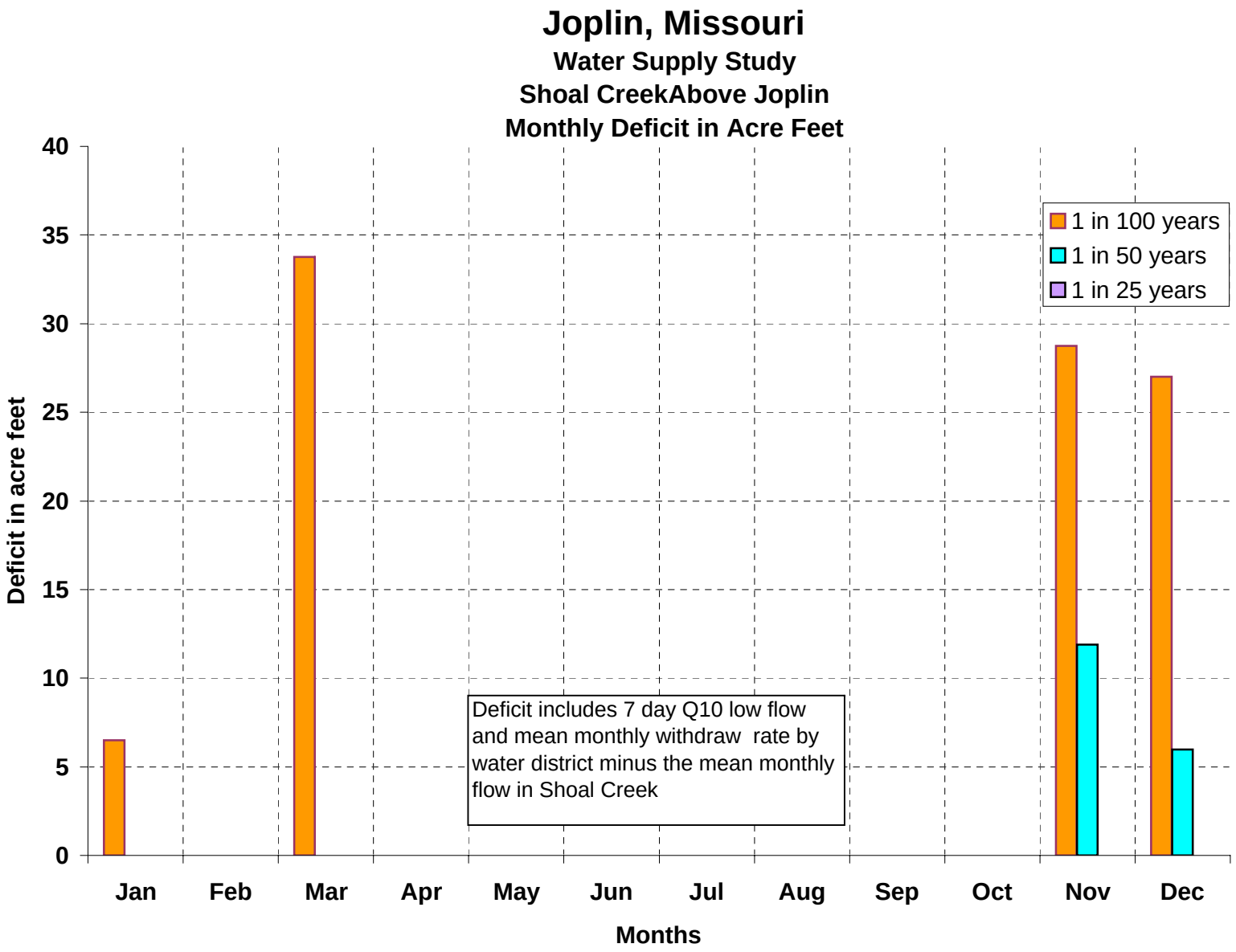

Joplin, Missouri
Water Supply Study
Shoal CreekAbove Joplin
Monthly Deficit in Acre Feet
Deficit in acre feet
40
35
30
25
20
15
10
5
0
1 in 100 years
1 in 50 years
1 in 25 years
Deficit includes 7 day Q10 low flow and mean monthly withdraw rate by water district minus the mean monthly flow in Shoal Creek
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 40.8.d

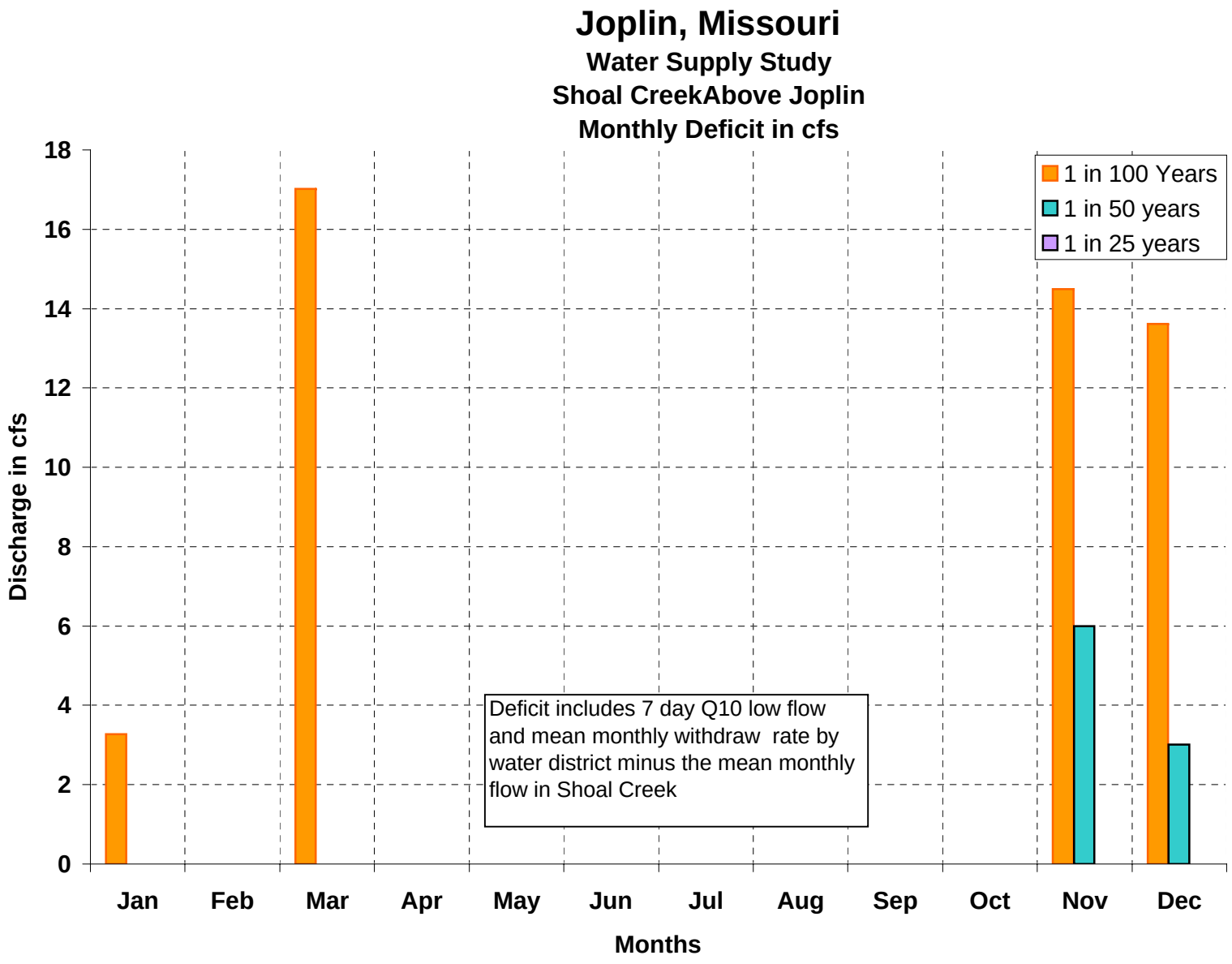

Joplin, Missouri
Water Supply Study
Shoal CreekAbove Joplin
Monthly Deficit in cfs
Discharge in cfs
18
16
14
12
10
8
6
4
2
0
1 in 100 Years
1 in 50 years
1 in 25 years
Deficit includes 7 day Q10 low flow and mean monthly withdraw rate by water district minus the mean monthly flow in Shoal Creek
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 40.8.e

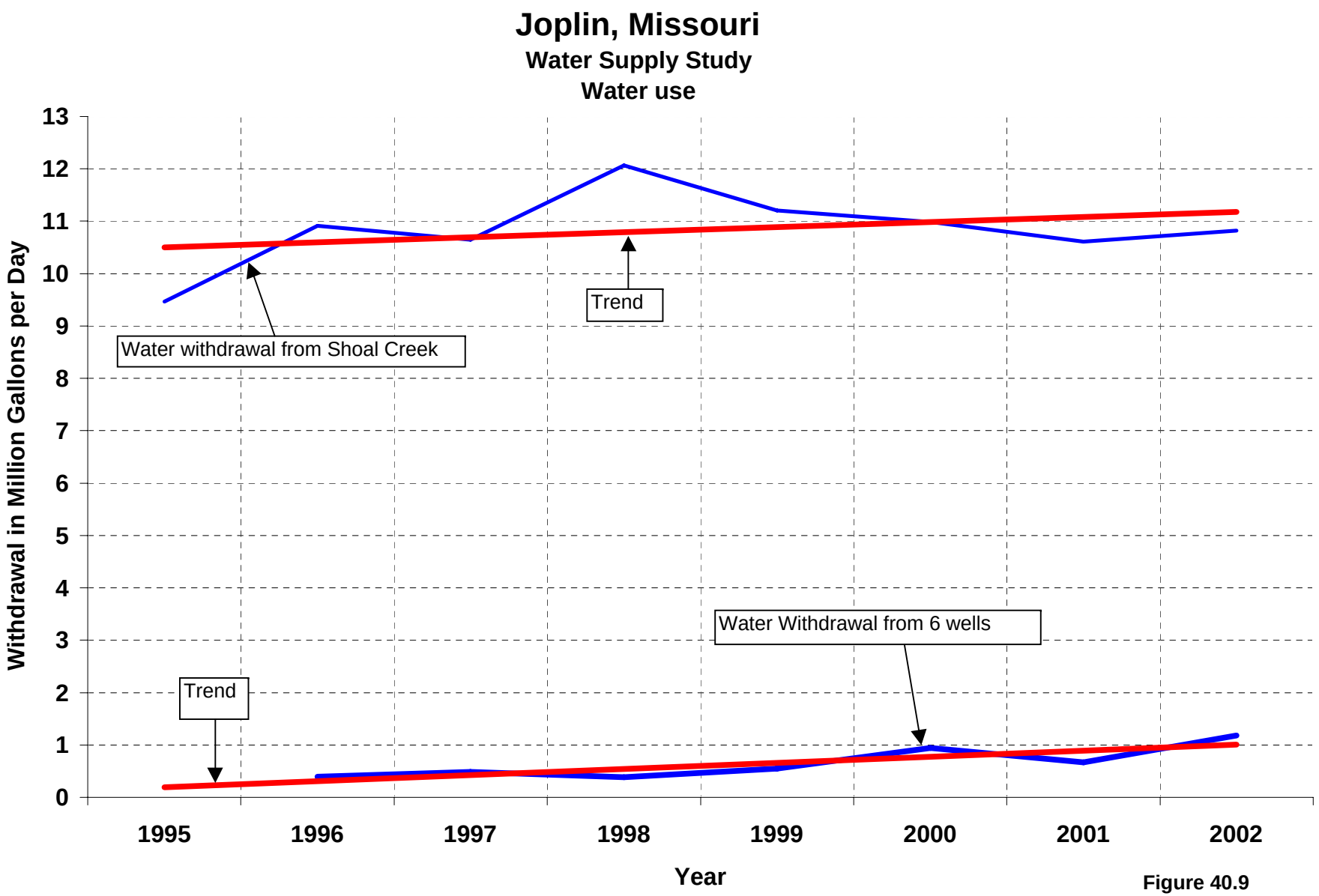

Joplin, Missouri
Water Supply Study
Water use
Withdrawal in Million Gallons per Day
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1995
1996
1997
1998
1999
2000
2001
2002
Year
Water withdrawal from Shoal Creek
Trend
Water Withdrawal from 6 wells
Trend

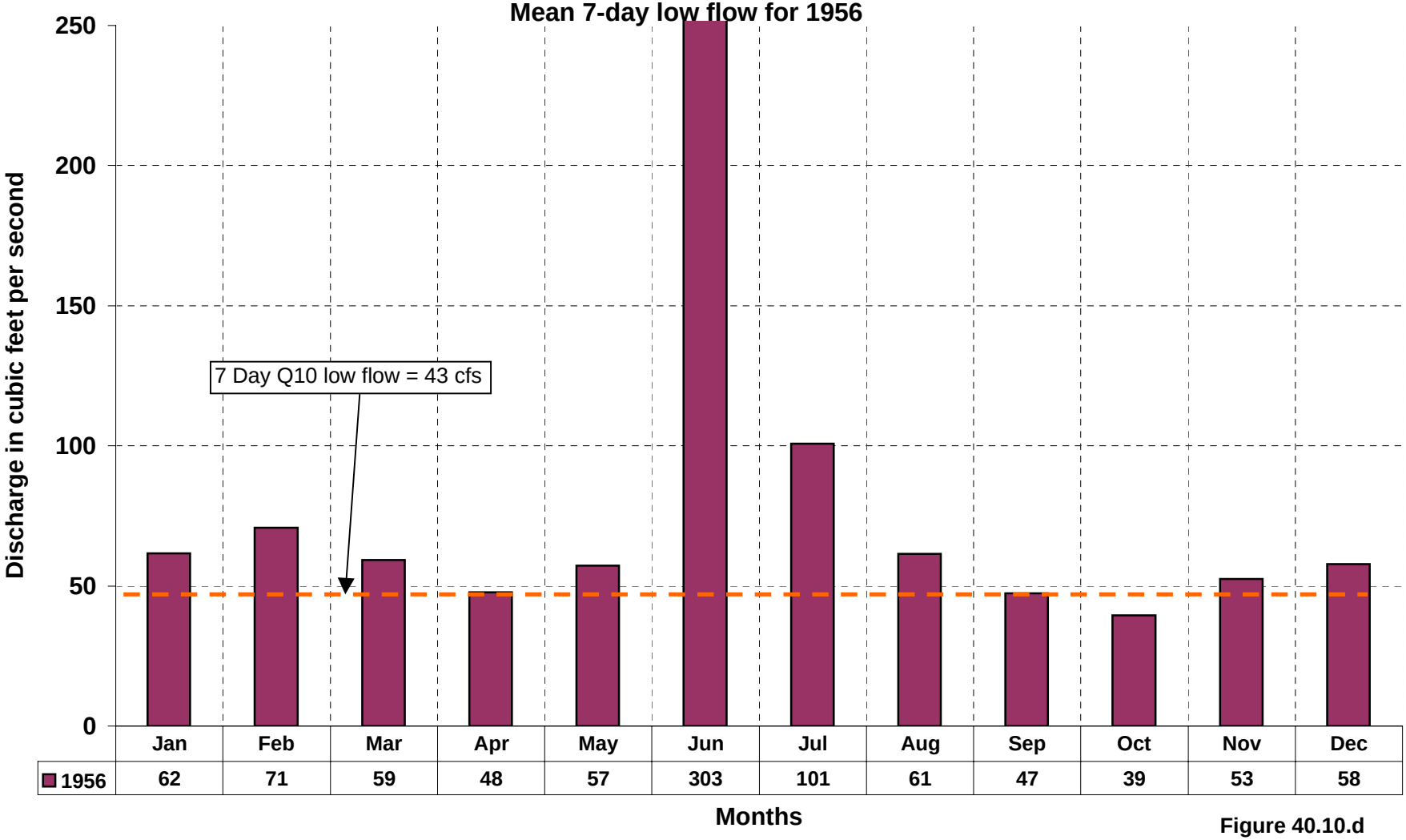
Figure 40.9

Joplin, Missouri

Water Supply Study

Shoal CreekAbove Joplin

Mean 7-day low flow for 1956



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1956	62	71	59	48	57	303	101	61	47	39	53	58

Months

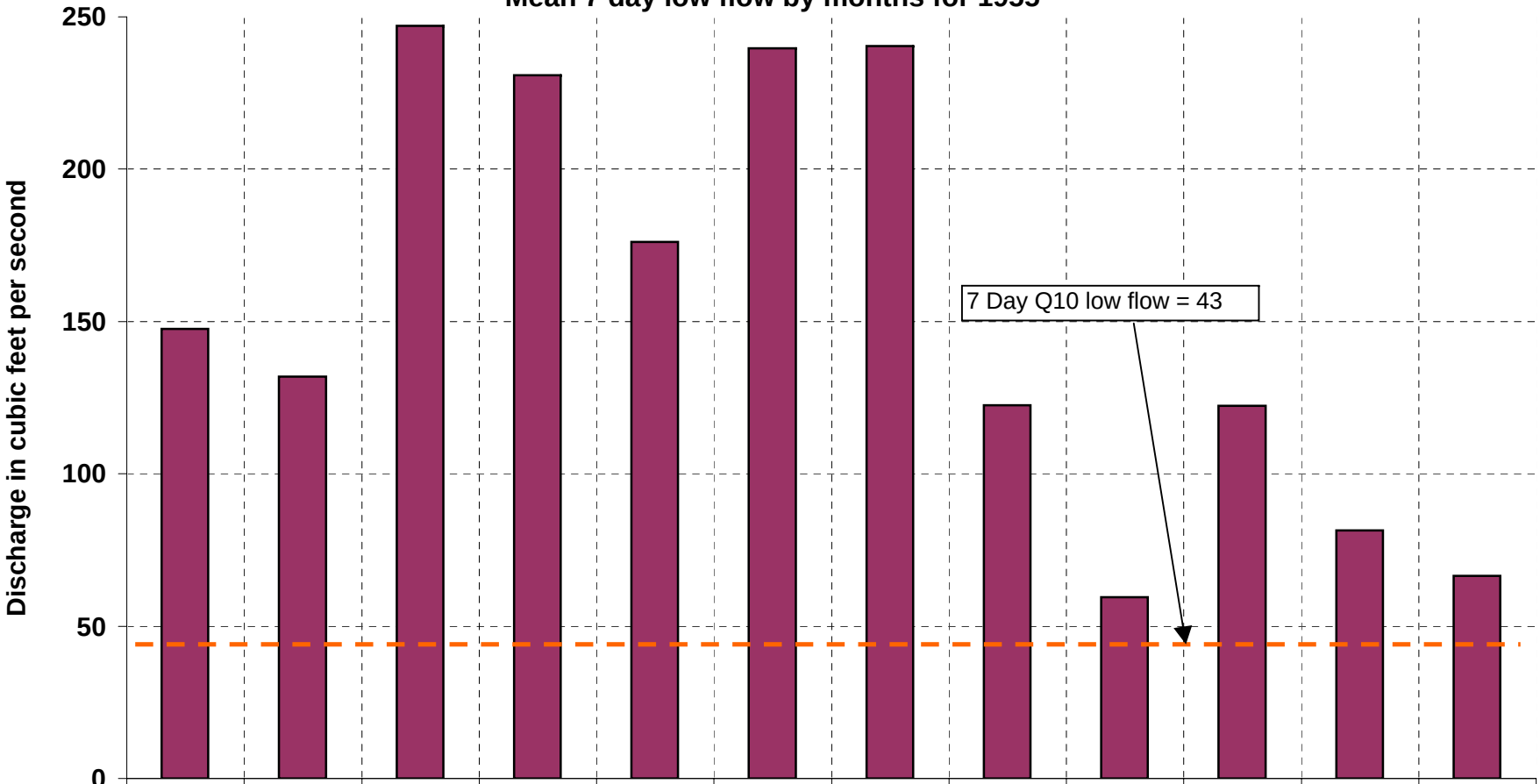
Figure 40.10.d

Joplin, Missouri

Water supply Study

Shoal Creek Above Joplin

Mean 7 day low flow by months for 1955



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1955	148	132	247	231	176	240	240	123	60	122	81	67

Months

Figure 40.10.c

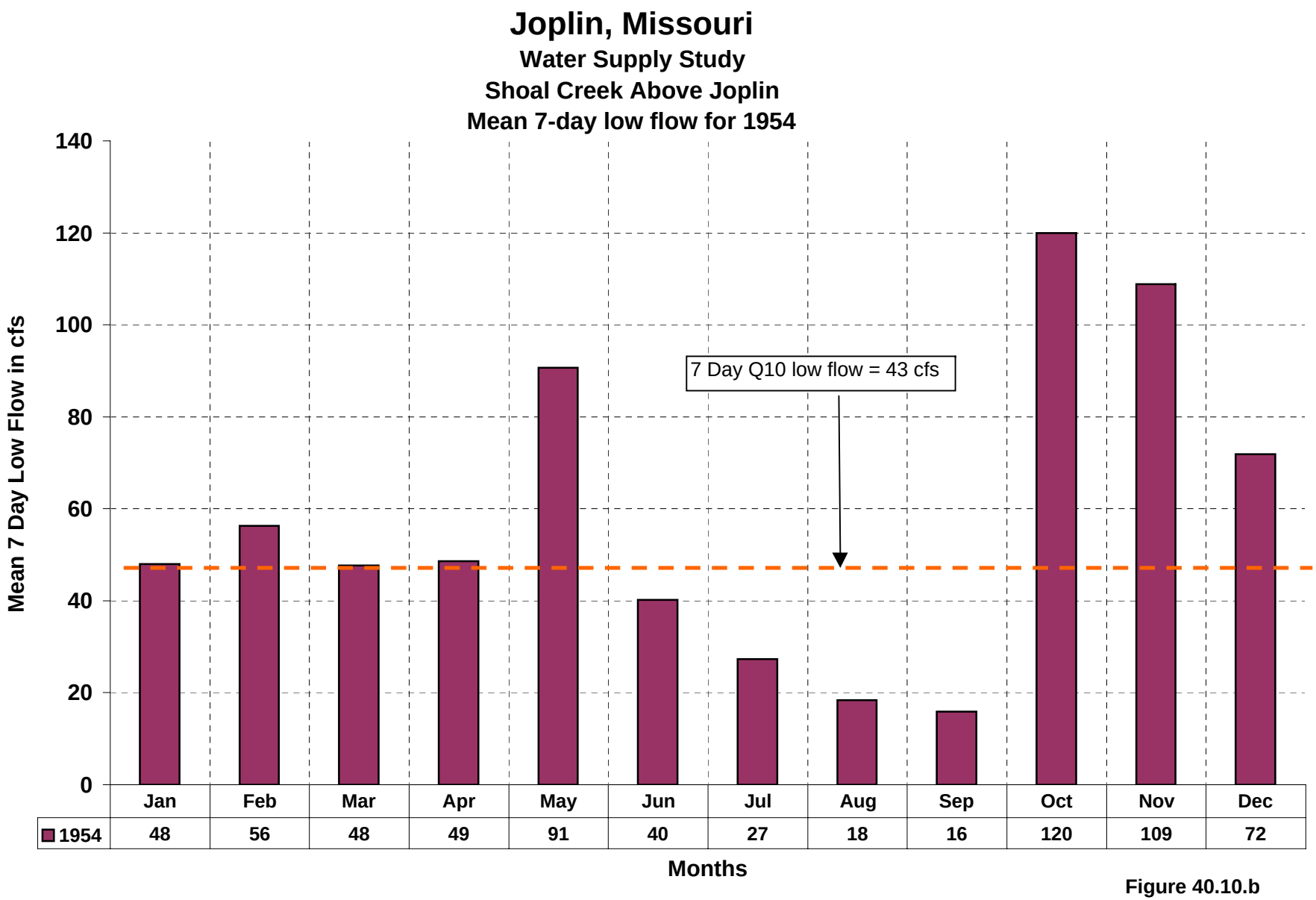


Figure 40.10.b